THE BINOCULAR MICROSCOPE OF THE SEVENTEENTH CENTURY.

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It is generally understood, I believe, that the binocular microscope is a modern invention—that it goes no further back than the one made about 1853, by Prof. J. L. Riddell, of the University of Louisiana. His instrument was a rude affair, made of two pieces of looking glass, which was improved by Prof. A. K. Eaton, of this city, by substituting for the mirrors a solid prism of glass made of two triangular prisms which were cemented together. Riddell adopted the improvement. This is the basis of the modern binocular microscope. Its perfection depends upon the equal division of the beam of light by the prism, or the nearness of that division into halves, so that the same amount of light may traverse each of the tubes to the eyes.

I never used but one instrument that did this, and that was made by J. Zentmayer, of Philadelphia. I tried it on the P. *angulatum* with the 1–5, 1–10, 1–15, 1–30, and 1–40th objectives, which resolved the frustule as satisfactorily as with a monocular. I have never found another binocular of this maker that would do this, and I have tried several.

But the first inventor of the binocular seems to have been Antonius Maria de Rheita, a Bohemian Capuchin, mathematician and astronomer, who published a work in 1645, under the title of "Oculus Enoch et Eliæ, sive Radius Siderio Mysticus," a rare book, which I found in the Astor Library of New York.

By a contemporary writer, R. P. F. Ioanne Zahn, who published an Optical Treatise in 1685, entitled "Oculus Artificialis Teledioptricus, sive Teliscopium," there is given a minute description of de Rheita's binocular microscope and telescope. This work is in my possession, and from it I hope to prove that the binocular microscope is no new thing.

In a letter to his friend, J. Caramuelis, dated Cologne, 24 April, 1643, de Rheita speaks of having detected most clearly, by means of his binocular telescope, "with the greatest surprise, admiration, and delight, the sacred Sudarium Veronicae sive faciem Domini maxima similitudina in astris expressum," in the sign of Leo, between the equinoctial and zodiacal circles. Zahn has given in his work a figure of our Lord's head as pictured on the handkerchief of St. Veronica. George F. Chambers, in his revision of Admiral Smyth's "Cycle of Celestial Objects," has given a reproduction of the figure and characterized it a "Pious Fraud," A. D. 1643.

I propose to give a translation from the Latin of such parts of the "Oculus" as have a bearing upon the binocular microscope, as follows:

"Since the distance between the eyes is not the same for all persons, first of all an artificer must ascertain this distance if he wishes to construct a tube perfectly fitting any one person. This can be best ascertained (as elsewhere has been shown and as de Rheita also has said) by the aid of a pair of compasses and a mirror. This distance serves for adjusting the first ocular lenses, since in the binocular tube the two other lenses nearest the eye must be similarly placed to each other—*e. g.*, if the center of the pupils of any person be distant A B, 22–100 ped. Rom. (Fig. 1 of plate), at this distance also from each other must the other first lenses be, *a b* and *c d*, as is shown by the figure, so that the center of the lenses *a b* and *c d* should meet at the points A and B. *

"Let us suppose one simple tube be constructed with a convex ocular lens of very great aperture, which shall be greater than the distance of the two eyes, *generally speaking* it will be impossible, by using one convex ocular lens, however large, for an image radiating from the tube to affect both eyes alike, for if the image radiating from the tube through one lens could affect both eyes alike, both eyes must be at the point of contact; but this is impossible, since both eyes cannot be at the same point at the same time, and thus all parts and points of the image cannot be transmitted to the same parts and points of both eyes at once. I have said *generally speaking*, because if one look at a mirror of very obtuse convexity and at a great distance

* The plate is reduced one-half from pencil tracings. The letters on Fig. 1 were accidentally omitted. A B are the ends of the straight line, *a b*, *b c* the diameters of the circles on the same line prolonged. The circles represent the eye lenses to be just as far apart as the observer's eyes.—W. H. S.

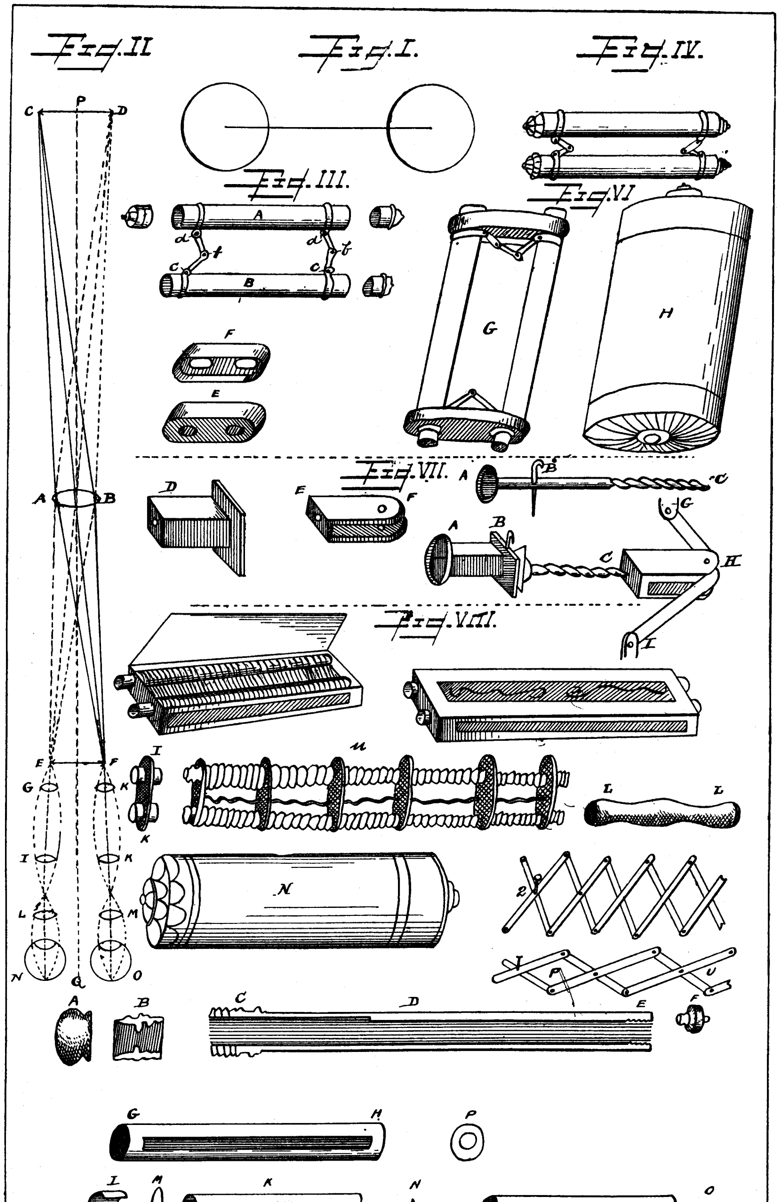
Fig. II
Fig. I.
Fig. IV.
Fig. III.
Fig. VI
Fig. VII.
Fig. VIII.

from the eyes, perhaps something can be effected; but it is of little practical use, for the objective lens must be of extremely long diameter to represent the object sufficiently large and near, so the tube would be obliged to be of enormous length."

III.

"A binocular tube can be constructed with one objective lens, when the image thrown from the objective lens can extend itself to a sufficient distance in the base of the divergence and thence again radiate through ocular lenses to both eyes. Thus the object C P D (Fig. 2), radiating through the objective lens, A B, forms the image E F; but the rays of the image, digressing from E, reach the eye N through the ocular lenses G I L, and from F reach the eye O through the lenses H K M. Thus a binocular tube can be constructed with one objective lens A B; but by this method the rays from the object reach the eye after being greatly refracted and diverging very far from the axis P Q of the objective lens, so that the image is never clear and distinct. Moreover, both eyes cannot see the whole of one object, nor is the same part of the object seen by both eyes, though more of the object can be seen by moving it about, but it will always be confused. Hence a tube thus constructed is never of much use."

IV.

"Even if one large lens be taken having two apertures at exactly the proper distance apart and both eyes look through these apertures at a single object, and thus see one and the same thing (which, however, seems impossible), nevertheless a perfect binocular tube cannot be formed, because just as the radiation from the object comes to both eyes by rays remote from the axis, and hence more refracted, so will the image possessed in the eye be indistinct and confused."

V.

"The best construction of the binocular tube is made by two telescopes exactly alike, so fitted to both eyes that the optical axis passes through one and the same object (Figs. 3, 4, 6, 7, and 8). The two objective lenses must be exactly alike; not only of the same shape, but also alike in magnifying power and in point of clearness. (The same care must be taken whether the lenses be concave or

convex.) Again, the telescopes must have the same "ordinate," so that not only the objective lines but also the eyes similarly placed will correspond precisely to each other; but the telescopes and their first ocular lenses must be as far apart as is the distance between the centers of the pupils of the two eyes. The telescopes should be so directed toward one and the same object as if there were but one aperture for both tubes, and through this aperture the object, brought wonderfully near, can be very distinctly seen."

VI.

"Since there are various kinds of telescopes, the ordinary Galilean, made of convexo-concave lenses, others convexo-convex, which can be made from pure convex lenses, and, indeed, again, out of these others can be so formed that they present objects inverted, as it is said to be the case with astronomical telescopes. Others present the object erect, but whether straight or curving inwards depends on the nature of the ordinate. The former can be made from four convex lenses, the latter from a plane glass and two very powerful lenses, etc. Thus also various binocular tubes can be made, depending on the ordinates of the telescope, provided that the ordinates be the same for the same binocular tube, taking the distance of the first ocular lens and the direction of both ordinates through one aperture, so to speak, so that the same object will be seen single and not double."

VII.

"For lesser binocular tubes, common telescopes not exceeding a foot in length are best, because those more than a foot long do not present the object completely enough. The smaller the telescopes the greater the object. Tubes of this kind are made with three lenses for each telescope, having their ordinates placed as indicated in number 13, cap. 5, *seq.* The proportion of the lines there indicated is also much approved."

VIII.

"How to join the two telescopes: The two tubes may be made of copper or brass plates, as in figure 3, where two tubes, A and B, are joined by brass hinges at *a b c;* then, where the tubes are placed,

both eyes are accommodated to any remote object, and the object will appear single and with great clearness. How the tubes may be joined, placed, closed, and covered is shown in figure 4. Likewise several movable rods similarly connected could be placed in each tube, but this method has disadvantages. Two tubes with their lenses arranged so as to be adapted to any vision are best constructed by cases or capsules as follows: Make a capsule of brass leaf in the form of an ellipse, as shown in H (Fig. 6). Make two apertures in the lesser capsules E and F as far apart as the distance between the eyes. These apertures must also be elliptical, as E and F in the figure. The size of the apertures should be such that the tubes or rods A and B, also C and D, would perfectly correspond.

"The two disks, E and F, of both tubes must be so firmly fastened that the tubes will not slide up and down too easily. Thus we now have all things arranged as in the figure G. This entire affair can be put into the greater capsule H and there encased. Thus it can be easily and safely carried about. The capsule H may be of wood, leather, or other material, and decorated to suit the taste."

IX.

"Since the distance between the two eyes does not differ much for many individuals, and also since the eyes easily accommodate themselves, many artificers fit their own eyes and fasten the rods in the tubes firmly in one position, so that they cannot be moved. I have made many such myself. Although they fit most people well enough, yet some eyes are unpleasantly affected after looking steadily for a long time. Least of all must such tubes be used for magnifying, unless they be adjusted to the distance between the eyes, since they harm the eyes not a little, and when used too much may even turn the eyes from their natural position (cross-eyed), as I have known happened to a certain nobleman. Thus it is always better to make the rods movable, so that they can be fitted to all eyes; yet it is allowable to make a little common binocular tube with movable rods, to be placed in a case after the manner of a little book, thus: Make a small capsule the size of the tubes which it is to contain, cover this with leather, and put on clasps just like a little book. Put two thin, wooden tablets at the ends where the ocular bands and objectives meet, but where the clasps are opened. These must be shoved aside, so that the eyes can look through the tubes. The cases may be so constructed that the open space between the

two tubes can hold the "ignitabulum" with its sulphur thread (match box) and the burning-glass for quickly making a fire in the field or anywhere you please. Above this space a cover of thin brass is placed, on which is fixed a magnetic needle. At the other end, which is covered with leather where the book closes, can be placed a movable circle to point to the moon, according to the hour of the night; and thus various other things can be added."

X.

"The long rods holding the lenses can be of various materials and shapes, but it is best to be so made that the lenses can be cleaned when necessary, for they will become dusty, no matter how carefully they are closed. That part of the tubes just before and just behind each ocular or objective lens should be so arranged that a small, linen cloth could be inserted through an aperture for the purpose of wiping the lens."

XI.

"In convexo-convex binocular tubes it is better for the first ocular lenses to be quite acute, so that the eyes can be placed nearer the same objects. They should always be a little more acute at the bottom than in simple convexo-convex tubes, since there is a greater clearness from the two eyes looking at the same thing. I have found these to be good proportions: The objective lenses remove the focus to a distance of 1½ feet; the middle ocular lens, equally convex on each side, has a diameter 35–100 Rom. feet; the first ocular lenses anywhere from a diameter 20–100. This is also a good binocular tube. Objective lenses remove the focus to a distance of two feet; middle lenses, equally convex, 40-100 diameter; first lenses, near the eye, 20-100 and 25-100 diameter. Another good tube, objective lenses at a focus of four feet. Middle lenses, equally convex on all sides, 50–100 diam. First ocular lenses, unequally convex, from diameter 30–100 and 35–100."

XII.

"Two convexo-convex telescopes enclosed in a case can be made adjustable to any vision in the following manner: Join the two telescopes by movable arms (as indicated in number 8 of this chapter) and through these arms place a spiral screw, which can lengthen or

shorten the telescope at will. This is shown in the 7th figure. A B C is a nail cylindrically round from A to B, spirally round from B to C. At B is a small nail, by which the large nail A B C is kept in place after being placed through the round aperture D. Thus the arms G H and I H, joining the two telescopes, can be contracted or extended. The form E F is placed upon H, and both arms, G H I, are held in place by a small nail passing through F and H. There the spiral part B C is placed through E. Now, if the head A of the nail A B C be turned this way or that, the arms G H and I H, joining the two telescopes, will be contracted or lengthened."

XIII.

"Cases to contain long binocular tubes should be made of strong solid wood and the tubes within so firmly made that they cannot bend; also that the glasses may at any time be taken out and the tubes differently placed, so as to be adapted to one vision or another. The upper part of the case must be so fitted with clasps that it can be closed or opened at pleasure. Long tubes of this kind can be made square like oblong beams, and may be made of plates of alloy of silver, lead, and iron, joined in several pieces, which can be easily separated from each other again. I saw a tube of this kind constructed by P. Rheita. It was at the Castle of Herbipolensus."

XIV.

"The longer the binocular the better, but the less convenient. How the inconvenience may be remedied I will show. Where these tubes are to be used they may be placed on long poles and easily extended or contracted. Tubes of this kind are very useful in war for viewing the enemy from afar, etc. I have selected the construction of a tube of this kind which I have heard P. Rheita used in his wonderful binocular telescope, whose lenses were not fitted to tubes but to a certain capsule which could be folded like a pair of bellows. The length of this was about ten hands when extended on a pole. They say that it made the moon of enormous size, which can easily be believed. The manner of constructing this kind of binocular tube is as follows: In the first place, make tubes out of leather folded like paper lanterns, or like the leather pipes used by hunters and bird-catchers for alluring beasts and birds. Crumpled leather tubes of this kind can be fitted to trans-

verse plates, in which are placed the glasses, as in A B C D E F, Fig. 8. These plates vary in number according to the length of the tube and hold the tubes perfectly straight, and also (since they have holds within) transmit to the eye a clear image, as is the case commonly in other telescopes. The transverse tablet is shown in G H in the figure. Again, that access may be had to the ocular glasses, some part of the transverse plate B and C can protrude on either side (as is seen in J K), to which is attached the leather tubes after the manner of a capsule. When the tubes are to be attached to the pole for use, cords or little chains, *a b c d e*, are put through all the transverse tablets, and at each of these tablets a knot is made, or in some other way the exact length of the desired extension is kept. Then nails at *a* and *f* fasten the tube to the pole and hold it at the desired extension. It can be constructed as in M and enclosed in the capsule N (for it must not be kept stretched on the pole all the time), and thus conveniently carried about. Instead of a pole, a contrivance like that shown in V P can be used, which can be extended to any length and again folded together, as in figure 2, and easily carried about; also one large leather tube holding both telescopes can be made, which can be extended at pleasure like a pair of bellows. Many of the contrivances might be mentioned for showing the object right side up in astronomical binocular tubes," &c.

Binocular Microscope.

Take for the objective glass a lens equally convex on all sides, of a diameter 80–100. The principal focus will be at a distance 40–100. Now remove the object a little beyond this distance, so that the rays behind the objective lens can converge to form an image. This image will be much larger than the object (as we have already shown in formula 2), for at double the distance it will be equal to the object itself, and from double the distance till you reach the focus it (the image) will always be larger, till at the focus there will be no image at all, because there the rays behind the lens are parallel. The object placed beyond double the distance of the focus always makes the image less and less than the object, till it is placed at so great a distance that rays falling upon the lens are considered parallel and the image is found in the distance of the principal focus. All this has been already shown elsewhere. Behind this greater image two other ocular lenses are placed. One near the

image itself is exceediagly convex on all sides, of a diameter 25–100. This arrangement shows the object very large and a little farther away than in ordinary composite microscopes shown in cap. 2.

On account of lengthening the tube or the greater distance of the lenses from each other (if a similar arrangement be made for both eyes), both eyes can easily look at one and the same object. The two "*prios*" lenses, ocular lenses, should be as far apart as is the distance between the two eyes, and all else arranged as in binocular tubes already explained. Such a microscope in its external form may be like the one shown in the figure, where A B is the case. Within are the two tubes, arranged as we have already shown in treating of binoculars. The object to be looked at is placed at C.